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The effect of coping materials and designs to the marginal adaptation of metal porcelain crowns

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***Abstract*---**The Metal porcelain crowns are still widely used because of the clinically satisfactory mechanical, esthetic, marginal and internal adaptation properties and affordable, but metal collars on the marginal labial are not aesthetically acceptable because of dark shadows in the cervical region which can be overcome by marginal porcelain butt joint coping design on the marginal labial. Recent clinical studies have introduced a type of cobalt chromium coping material that is biologically more biocompatible than nickel chromium which can cause allergic reactions. In this study, Ni-Cr and Co-Cr coping materials were used with full metal collarless and modified metal collarless coping designs. The purpose of this study was to determine the effect of material and coping design on the marginal adaptation of metal porcelain crowns. This type of research is experimental laboratory. The typodontic central incisor teeth were prepared and duplicated using CAD/CAM to become zirconia and implanted in acrylic resin blocks for the manufacture of 24 porcelain metal samples. The application of an opaque layer on both coping

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designs was burned at 975˚C followed by the application of dentin, enamel and glazing. The measurement of the marginal adaptation value in the porcelain metal sample group was carried out using a Stereomicroscope (Olympus SZX 10) which was computerized using Olympus Stream Software in micro meters (μm). The sample is placed under a stereomicroscope at five reference points where the marginal gap size will be calculated. Statistical data by T-Test Independent showed a significant difference with the mean value of the marginal gap and standard deviation of the Ni-Cr coping material with the full metal collarless coping design (119.76 ± 25.8) µm, and the Co-Cr coping material was (90.03 ± 12.03) µm. The mean value of marginal gap and standard deviation of Ni-Cr coping material with modified metal collarless coping design was (87.82 ± 23.36) µm, and Co-Cr coping material was (59.41 ± 11.48) µm. The results of the Independent T-Test showed that there was a significant difference between Ni-Cr and Co-Cr coping materials with a full metal collarless coping design on the marginal adaptation of metal porcelain crowns with p value = 0.029 ($p < 0.05$). Significant difference of NiCr and Co-Cr coping materials with modified metal collarless coping design on the marginal adaptation of metal porcelain crowns with p value = 0.023 ($p < 0.05$). Significant difference in the design of full metal collarless and modified metal collarless coping with Ni-Cr coping material on the marginal adaptation of metal porcelain crowns with p value = 0.049 ($p < 0.05$). Significant differences in the design of full metal collarless and modified metal collarless coping with Co-Cr coping material on the marginal adaptation of metal porcelain crowns with p value = 0.001 ($p < 0.05$). The results of the study concluded that the Co-Cr coping material with the modified metal collarless coping design has the best marginal adaptation and is clinically acceptable, so this design can be recommended for clinical applications in cases that require maximum esthetics.

***Keywords*---**Coping Material, Coping Design, Marginal Adaptation, Porcelain Metal Crown.

Introduction

Metal porcelain crowns have clinically satisfactory mechanical, aesthetic, marginal adaptability and internal properties [1]. Nickel-chromium alloy has become the most popular base metal alloy for porcelain metal crown restorations [2] . Ni-Cr has a wide range of physical and mechanical properties such as high yield strength and modulus of elasticity so that a greater force is required during the combustion process, has a greater percentage of elongation which is used as an index to predict durability during combustion and makes it more adaptable. Ni-Cr has low corrosion resistance and is not biocompatible because nickel can cause allergic reactions. In addition, the addition of beryllium to Ni-Cr which functions as a hardener, grain structure refiner, and to reduce the combustion temperature is carcinogenic, but is still within the clinically acceptable threshold of 0.002 ppm [3]. Concerns about the toxicity due to the use of nickel and beryllium, although still within clinically accepted limits, have spurred researchers to develop Co-Cr alloys as an alternative that can be used in porcelain metal crown restorations. Co-Cr alloys were developed because they are more biocompatible, resistant to corrosion, stable in the biological environment, have a high modulus of elasticity at a more affordable cost. Co-Cr contains of molybdenum (Mo) and tungsten (W), which function as reinforcing agents so that Co-Cr has better strength and is widely used in the manufacture of metal frameworks [2,4] . Metal collar on the gingival margin in both Ni-Cr and Co-Cr can cause the gingival discoloration to become dark and unaesthetic, making it difficult for patients to accept. This phenomenon is known as the umbrella effect, which is characterized by gray gingival margins and darkening of the interdental papilla [5,6] . Porcelain metal crown margin modification has been carried out in an effort to meet the aesthetic demands of the patient and maintain the health of the periodontium. Several researchers have modified the metal collar design to overcome this situation. The researchers modified the metal collar design by shortening the metal collar from the labial edge so that the dark color of the metal could be masked by the porcelain thickness. From several studies, the best metal collar designs to overcome the umbrella effect are full metal collarless and modified metal collarless [5,6,7]. The full metal collarless coping design features a thin metal layer on the labial axial walls covered by an opaque layer of porcelain and dentin. This design can prevent plaque retention due to the well glazed surface of the dentin layer on the marginal walls. In the design of the porcelain metal crown modified metal collarless or so-called porcelain butt joint which is achieved by shortening the metal edge 1-3 mm in the labial area [5,6.] This design will increase light transmission. This was caused by the increasing thickness of the dentin and porcelain enamel layers in the marginal area. [5,6] In modified metal collarless, there is thicker porcelain at the gingival margin thereby reducing distortion during the firing process which affects the marginal adaptation of the porcelain metal crown. Marginal adaptation plays an important role in the long-term success of a porcelain metal crown. The adaptability of a restoration can be defined in terms of non-conformance measured at various points of the restoration and tooth along the internal surface, at the margins, or on the external surface of the casting. Poor marginal adaptation indicates the available cement space, namely the space between the restoration and preparation, leading to exposure of the luting material to the oral environment and accumulation of plaque. These gaps can be seen as physical roughness that can lead to periodontal inflammation, caries, and loss of restorations [2] . With good marginal adaptability in abutment teeth, it not only prevents secondary caries but also affects the reaction of the surrounding periodontium. Metal porcelain crowns have good marginal adaptability, giving porcelain a natural translucent aesthetic and advantages in metallic structural strength. The acceptable vertical marginal adaptation of a restoration ranges from 10 - 160 μm. Clinically, for the long-term resilience of a restoration, the acceptable marginal adaptation difference is 40–120 μm [8] . In selecting the type of alloy for coping, one of several important factors to consider is the dimensional accuracy of the resulting coping. Coping must adapt precisely to the tooth being prepared, with good marginal adaptation. This can be found in Ni-Cr and Co-Cr which have some better properties than gold alloys. Numerous studies have been carried out to examine the marginal adaptation of metal porcelain crowns to Ni-Cr and Co-Cr copings. In the study of Sundar et al (2014) the marginal gap of the porcelain metal crown with Co-Cr coping is 53.63 11,375 µm. In addition, in Fahmy's (2012) study, the marginal gap of metal porcelain crowns with Ni-Cr coping is 50-60 µm. In terms of margin coping design, research by Fahmy (2012) shows that the modified metal collarless has better marginal adaptation compared to the other two full porcelain crowns, namely IPSEmpress and IPS Empress CAD (Fahmy, 2012).

Several types of alloys that are often used have been described in several studies. Nickel-chromium alloys have become the most popular base metal alloys for porcelain crown restorations (Kane, 2015). The addition of carcinogenic beryllium to Ni-Cr has a negative effect on human biological reactions although it is still within a clinically acceptable threshold. In response to concerns about the toxicity of nickel and beryllium, the Co-Cr alloy of choice was developed for use in porcelain metal crown restorations. This development is based on the properties of Co-Cr alloys, which are more biocompatible, resistant to corrosion, stable in the biological environment, have a high modulus of elasticity, better strength, which are widely used to make metal frames (Kane, 2015; Tamac, 2014).

Marginal adaptation plays an important role in the long-term success of a porcelain metal crown. The adaptability of a restoration can be defined in terms of the suitability measured at various points of the restoration and the tooth along the internal surface, at the margins, or on the external surface of the casting. Poor marginal adaptation indicates the large amount of available cement space, namely the space between the restoration and preparation, leading to exposure of luting material to the oral environment and accumulation of plaque. This gap can be seen as physical roughness that can lead to periodontal inflammation, caries, and loss of restorations (Kane et al., 2015). The vertical marginal gap of an acceptable restoration ranges from 10 - 160 m. Clinically, for the durability of a long-term restoration, the acceptable marginal gap difference is 40-120 µm (Doddy et al., 2019). The types of alloys used, namely Ni-Cr and Co-Cr, have good dimensional accuracy so that they can adapt precisely to the prepared tooth and produce good marginal adaptation. With the modified metal collarless margin design, the porcelain thickness is increased thereby reducing distortion during the firing process that affects marginal adaptation. In Fahmy's study (2012), with Ni-Cr coping, the average value of the marginal gap in the modified metal collarless crown is 50-60 m, better than the two types of full porcelain restorations (IPS Empress and IPS Empress CAD). Several other studies using Co-Cr coping with conventional designs, mention the results of marginal gap differences that are still acceptable. In Sundar's research (2014), the marginal gap is 53.63 µm. Meanwhile, in Doddy's (2019) study, the marginal gap is 38.13 µm. In Ammar's study (2015), the marginal gap is 25.25 µm. In Gaikwad's 2018 study, the marginal gap is 39.53 µm. Based on several considerations of the material and the design of the coping, the researcher needs to evaluate the effect of the material and the design of the collarless margin coping on the marginal adaptation of the porcelain metal crown.

Materials and Methods

Sample Making

Typodont tooth structure preparation was carried out using a micromotor and handpiece attached to the surveyor to determine the recommended thickness. This procedure was carried out based on previous studies[10,11]. The supporting structures of the teeth were prepared using a micromotor handpiece according to the procedure and the thickness of the tooth preparation recommended by Shillingburg et al (2012) and Rosenstiel et al (2016), reduction in the labial (1.5 mm), mesial (1 mm), distal layers (1 mm), palatal (± 1 mm), and incisal (2mm). and produces a 1.5 mm shoulder-shaped cervical suffix in the labio-marginal to the mesio-distal region and merges in the palatal area. The prepared typodont teeth were sent to the lab for scanning using CAD/CAM and milling to produce monolithic zirconia. Then the roots of the zirconia teeth were implanted into a 3x3x3 cm swapolymerized acrylic block.

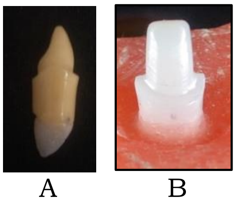

Figure 1. (A) Prepared Typodont teeth, (B) Dai Zirconia

Manufacture of Ni-Cr and Co-Cr. Metal Copings

First, the spacer application was carried out on the surface of the dai with the exception of a 1 mm marginal gap. Then the coating process is carried out using a liquid inlay wax followed by measuring the thickness with a caliper. The samples were then fabricated into four groups, namely groups A, and C, each of which consisted of 6 units of inlay wax crown only placed on the edge of the labio marginal surface area (0.3 mm), while groups B and D had inlay wax at 1.5 mm above the labiomarginal surface area.

The assembly steps for all 24 green inlay waxes were performed, and implantation into the moffel was carried out using an investment cast at a powder-to-liquid ratio according to the manufacturer's instructions in a vacuum mixer. The burn out procedure is carried out through a burn out oven where in the casting procedure the composition is Ni 61.27%, Cr 26.44%, Mo 10.46 %, Mn 0.001 %, C 0.02 %, Be 0.1%. The coefficient of thermal expansion is 14.1 x 10¯6 K¯1 and the modulus of elasticity is 115 GPa. Composition of Co 60.2%, Cr 30.1%, Mo <1.0%, Ga 3.9%, Si<1%, Fe<1%, B<1%, Li<1.0% and coefficient of thermal expansion 14.5 x 10 6 K¯1 and modulus of elasticity 234 GPa. Then, cleaning the metal cover by sandblasting using 50 micron aluminum oxide (Al2O3) in a sandblasting machine. Furthermore, the sample was oxidized in a vacuum furnace at a temperature of 980oC and ultrasonic cleaning with distilled water for 10 minutes.

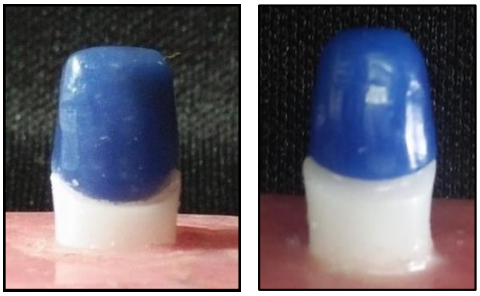
A B

Figure 2. Wax-Up Coping (A) inlay wax placed only on the edge of the labio marginal surface area (0.3 mm), (B) inlay wax on 1.5 mm of the labio marginal surface area

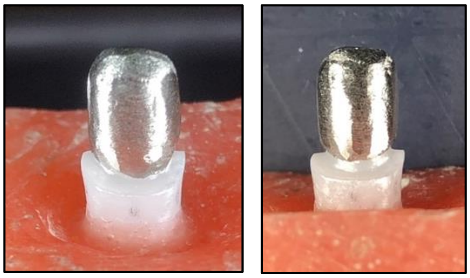
A B

Figure 3. (A) Full Metal Collarless (B) Modified Metal Collarless

Porcelain Layering

The thickness of the Vita VMK master opaque layer in the marginal labio in groups A, B, C and D : (0.2 mm). This is done through a series of condensation vibrations 10 times, and the sample is placed at a combustion temperature of 975^{o}C. The thickness of the dentin layer above the opaque layer in the labio-marginal area: A, B, C and D : 1.0 mm was carried out through vibrating condensation with 10 repetitions, but the sintering temperature was carried out at 965oC. The thickness of the dentin layer in the labio-marginal area: Groups A and C (-), Groups B and D (0.3 mm) was carried out by heating treatment at a temperature of 955oC. Finally, the glazing process was carried out at a temperature of 945^{o}C

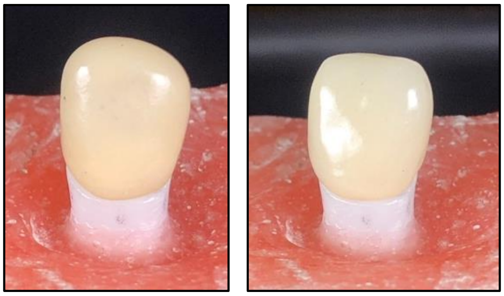
A B

Figure 4. (A) Full Metal Collarless (B) Modified Metal Collarless

Marginal Adaptation Measurement

All samples of metal-porcelain crowns were measured marginally using a stereo microscope. The basic model of zirconia is characterized by reference lines on the facial surface, namely the proximal mesial (Line A), between the mesial and middle areas (B Line), middle (C Line), and between the middle and distal (D line), and proximal. distal (line E). Measurements carried out with the support of the Olympus software stream from the edge of the metal porcelain crown to the edge of the cervical edge of the zirconia in five reference lines.

Results

The measurement of the marginal gap in the sample was carried out using a Stereomicroscope (Olympus SZX 10) which was recorded computerized using Olympus Stream software expressed in units of micro meters (μm), with a magnification of 6.3x. In the Ni-Cr coping material group with full metal collarless coping design the smallest marginal gap is 88.21 m and the largest marginal gap is 154.38 m. The Ni-Cr coping material group with the modified metal collarless coping design obtained the smallest marginal gap of 68.21 μm and the largest marginal gap of 132.18 μm. Co-Cr coping material group with full metal collarless coping design obtained the smallest marginal gap which is 77.23 μm and the largest marginal gap is 111.47 μm and in the Co-Cr coping material group with modified metal collarless coping design the smallest marginal gap is 43 .18 μm and the largest marginal gap is 72.56 μm. The smallest marginal gap from all groups was found in the Co-Cr coping material group with a modified metal collarless coping design, which was 43.18 μm, and the largest marginal gap was found in the Ni-Cr coping material group with a full metal collarless coping design, which was 154.38 μm.

Table 1. The average value of the marginal gap of metal porcelain crowns (μm) with Ni-Cr and Co-Cr coping materials with full metal collarless and modified metal collarless coping designs

Sample	A	B	C	D
	Ni-Cr *Full Metal Collarless* (μm)	Ni-Cr *Modified Metal Collarless* (μm)	Co-Cr *Full Metal Collarless* (μm)	Co-Cr *Modified Metal Collarless* (μm)
1	154,38**	132,18**	111,47**	72,56**
2	143,46	80,51	77,23*	57,89
3	112,06	93,94	89,89	70,33
4	88,21*	78,25	94,35	62,64
5	123,60	68,21*	83,49	49,89
6	96,96	73,82	83,77	43,18*
$\overline{X}$ ± SD	119,76 ± 25,8	87,82 ± 23,36	90,03 ± 12,03	59,41 ± 11,48

Description: * smallest value ** largest value

The mean value of the marginal gap was analyzed by univariate test. The average value of the marginal gap in Ni-Cr coping material with full metal collarless coping design is 119.76 μm, with a standard deviation (SD) of 25.8 μm. The mean marginal gap in Ni-Cr coping with modified metal collarless coping design is 87.82 μm, with standard deviation (SD) is 23.36 μm The average value of the marginal gap in Co-Cr coping materials with full metal collarless coping design is 90.03 μm, with a standard deviation (SD) is 12.03 μm and the mean marginal gap in Co-Cr coping materials with modified metal coping designs. collarless was 59.41, with a standard deviation (SD) of 11.48 μm.

The results of the analysis using Independent T-test showed that there was a significant effect on Ni-Cr coping materials with full metal collarless and modified metal collarless coping designs on the marginal adaptation of metal porcelain crowns with p value = 0.049 ($p<0.05$) (Appendix 6) (Table 2)

The results of the analysis using the Independent T-test showed that there was a significant effect on Co-Cr coping materials with full metal collarless and modified metal collarless coping designs on the marginal adaptation of metal porcelain crowns with p value = 0.001 ($p <0.05$) (Table 3)

From the results of the Independent T-test obtained a significance of p = 0.029 ($p < 0.05$), this indicates that there is a significant effect of the full metal collarless coping design with Ni-Cr and Co-Cr coping materials on the marginal adaptation of metal porcelain crowns (Table 4)

From the results of the Independent T-test obtained a significance of p = 0.023 ($p < 0.05$), this indicates that there is a significant effect of the modified metal collarless coping design with Ni-Cr and Co-Cr coping materials on the marginal adaptation of metal porcelain crowns (Table 5).

Table 2 Effect of Ni-Cr Coping Materials with Full Metal Collarless and Modified Metal Collarless Coping Designs on Marginal Adaptation of Metal porcelain crowns

Coping Material	Marginal Adaptation (μm)			
	n	*Full Metal Collarless*	*Modified Metal Collarless*	p
		$\overline{X}$± SD	$\overline{X}$ ± SD	0,001*
Co-Cr	6	90,03 ± 12,03	59,41 ± 11,48	

Note: * significant ($p < 0.05$)

Table 3. Effect of Co-Cr Coping Materials with Full Metal Collarless and Modified Metal Collarless Coping Designs on Marginal Adaptation of Metal porcelain crowns

Coping Material	Marginal Adaptation (µm)			
	n	*Full Metal Collarless*	*Modified Metal Collarless*	p
		$\overline{X}$ ± SD	$\overline{X}$ ± SD	
Ni-Cr	6	119,76 ± 25,8	87,82 ± 23,36	0,049 *

Note: * significant ($p < 0.05$)

Table 4 Effect of Full Metal Collarless Coping Design with Ni-Cr and Co-Cr Coping Materials on Marginal Adaptation of Metal porcelain crowns

Coping Material	Marginal Adaptation (µm)		
	n	*Modified Metal Collarless*	p
		$\overline{X}$ ± SD	
Ni-Cr	6	87,82 ± 23,36	0,023*
Co-Cr	6	59,41±11,48	

Note: * significant ($p < 0.05$)

Table 5. Effect of Collarless Modified Metal Coping Design with Ni-Cr and Co-Cr Coping Materials on Marginal Adaptation of Metal porcelain crowns

Coping Material	Marginal Adaptation (µm)		
	n	*Full Metal Collarless*	p
		$\overline{X}$ ± SD	
Ni-Cr	6	119,76 ± 25,8	0,029*
Co-Cr	6	90,03±12,03	

Note: * significant ($p < 0.05$)

Discussion

The coefficient of thermal expansion is the degree of expansion or contraction of a material in the heating or cooling process. The coefficient of thermal expansion of metal is 13.5-14.5x10¯6/°C while the coefficient of thermal expansion of porcelain is 12-13.5x10¯6/°C. Metal and porcelain must have a suitable coefficient of thermal expansion, which is between 0.5-1x10¯6/°C, so that the porcelain is only slightly stressed during the cooling process. The higher the coefficient of thermal expansion, the greater the contraction during the cooling cycle. This corresponds to a large expansion during the combustion cycle will be followed by a large contraction in the cooling cycle. A high coefficient of thermal expansion indicates more expansion on heating and more contraction on cooling. During the porcelain combustion cycle, there is an interaction between the metal and the porcelain which binds through the oxide layer. During the cooling cycle, the contraction of the two materials together must be compatible or the porcelain will crack when cooled to room temperature. Metal should contract slightly more than porcelain to reduce the risk of fracture during cooling. Thus, the coefficient of thermal expansion for metal should be about 0.5 x10 6/°C greater than that of porcelain. Similar to the melting range, not all porcelain metals are compatible in terms of 12 . thermal contraction expansion compatibility During the cooling cycle of the sintering temperature, metal and porcelain contract at different rates due to the difference in their coefficient of thermal contraction, whereas porcelain has a smaller coefficient of thermal contraction than metal. Meanwhile, the chemical bonds that exist between the metal and porcelain serve to prevent the metal and porcelain from separating, so this condition forces the metal and porcelain to adjust their respective dimensions in the face of stresses that develop during the cooling cycle. This is in accordance with the value of the coefficient of thermal expansion, which has a higher coefficient of thermal expansion will contract more, where the component that contracts more will be pulled by adjacent components, which contract less, and at the same time, the material that contracts more some will be compressed by others. The change in dimensions is controlled by a certain stress acting on each of the two components. In this case, a higher value of the coefficient of thermal expansion in metal will cause more contraction, while a smaller value of the coefficient of thermal expansion in porcelain causes less contraction. The metal that contracts more will be pulled by the less contracted porcelain, then at the same time the porcelain will experience compression so that shrinkage occurs and affects the marginal adaptation of the porcelain metal.

A group of Ni-Cr coping materials with a full metal collarless design, the coping ends on the axial labial coronal wall with a thickness of 0.3 mm and the thickness of porcelain is 1.2 mm. The occurrence of contraction during the cooling cycle will pull the metal towards the porcelain and at the same time the porcelain will experience compression resulting in a shrinkage that is difficult to compensate for due to the porcelain thickness being only 1.2 mm in the marginal labio region, causing the marginal gap in this design to become larger. large and the marginal adaptation is not good. The magnitude of the marginal gap in the full metal collarless design is in accordance with the statement of Gemalmaz and Alkumru (quoted from Handal et al 2016) who evaluated the thermal cycle distortion on 3 porcelain fused to metal units at different combustion, and the distortion was seen to be greater after the porcelain application [13,14]

The group of Ni-Cr coping materials with a modified metal collarless design, the coping is 1.5 mm shorter than the cervical labio marginal suffix. Porcelain on the marginal labio of this design has a thickness of 1.5 mm, which is the minimum thickness to achieve aesthetics. When porcelain is fired, with the thickness of the porcelain in this design, distortion and cracking can be minimized by forming a solid mass after burning. At the time of contraction in the cooling cycle, the porcelain is compressed by the tensile force on the metal contraction, so the thicker porcelain in this design is able to compensate for the shrinkage so as to obtain a smaller marginal gap and good marginal adaptation. This is in accordance with the research of Fahmy (2012), the Ni-Cr coping material with a modified metal collarless design of 1.5 mm above the cavosurface angle has marginal adaptation better than the two types of full porcelain restorations [7,15]

Ni-Cr metal contains about 70% nickel and 16% chromium. The important minor components are about 2% aluminum and 0.5% beryllium. Aluminum and nickel form intermetallic compounds (Ni3Al) which contribute to strength and hardness while beryllium decreases the melting range, increases fluidity and improves grain structure. Other minor elements include molybdenum, tungsten, manganese, cobalt, silicon, and carbon. The beryllium content in Ni-Cr is carcinogenic but still within clinically acceptable limits. Beryllium-containing Ni-Cr yields a much better bond to porcelain than beryllium-free Ni-Cr. The bonding of porcelain metal to Ni-Cr without beryllium is inhibited by the formation of a thick underlying oxide that affects marginal adaptation.

During the porcelain firing cycle, dimensional changes occur during casting as a result of an increase in temperature. This change has many causes, such as changes in the entire alloy due to some metallurgical mechanisms, distortion in the alloy due to residual stresses from the casting process and oxidation of the alloy. In collarless full metal, other factors that involve changes in marginal adaptation, including correction of build up and distortion of porcelain margins during firing, also affect marginal adaptation changes. In accordance with Yoon's research (2005) that shrinkage and gravity on porcelain can be the cause of distortion (Yoon et al, 2005). However dimensional changes occur in most laboratory stages, the final restoration may not be exactly the same size as the pattern. The causes of metal distortion include the release of pressure resulting from the solidification process of casting techniques, such as reducing the shrinkage of the alloy in investment casting and the release of stress on cooling the porcelain application surface. [5.16]

Based on the variation of the marginal gap after porcelain firing, Buchanan et al concluded that the first firing procedure showed a tendency to increase the marginal gap, then subsequent firing decreased the marginal gap compared to the metal conditioning procedure. Factors that contribute to the distortion of metallic coping include casting release due to comprehensive stresses as a result of the initial oxidation cycle, formation of an oxide layer on the inner surface of the porcelain metal alloy during heating, thermal stress mismatch, contamination of the inner surface of the coping with porcelain, reduced resilience of the metal. due to the rigidity of porcelain, development of alloy granules leading to a narrowing of the crown diameter, improper support of the coping during firing, inadequate coping design in the gingival area, overall inadequate coping design, alloy type, and preparation design [13,17]

Co-Cr has high yield strength and hardness values, namely 870 MPa and 380 kg/mm2. With high yield strength and hardness values, it will minimize the distortion that occurs during metal contraction during the cooling cycle which will provide a smaller marginal gap and good marginal adaptation. It also protects the porcelain metal crown from the onset of plastic deformation which will lead to porcelain debonding, especially in the thin cervical region (Youssef, 2014). The metal coupling used must have an optimal thickness to prevent distortion during the combustion process. The thickness of the metal coping ranges from 0.2-0.7 mm, for good strength and rigidity, the thickness of the coping used also depends on the thickness of the preparation carried out [11,12,18,19]

Co-Cr contains about 60% cobalt and 25% to 30% chromium, which provides corrosion resistance. It also contains small amounts of molybdenum, aluminum, tungsten, iron, gallium, copper, silicon, carbon and platinum. Manganese and silicon increase the fluidity of the molten alloy, molybdenum, tungsten, and carbon are the main hardening and strengthening elements. The chromium on the alloy surface is rapidly oxidized to form a thin layer of chromium oxide, which prevents the diffusion of oxygen into the underlying metal and increases its corrosion resistance. Chromium also strengthens alloys by solution hardening. In general, the higher the chromium content, the better the corrosion resistance of the alloy. Molybdenum serves to improve the grain structure by forming more regions for crystal nucleation during the solidification process. This has the added benefit of producing a significant solid solution hardening effect, an effect that is shared with the addition of iron. Carbon, which is only present in small amounts, plays a significant role in changing the strength, hardness, and resistance of an alloy. Carbon can combine with other elements to form carbides which increase strength and hardness. Carbide distribution also depends on casting temperature and cooling rate, with discontinuous carbide formation at the grain boundaries being preferable to continuous carbide formation. Co-Cr is more difficult to manipulate because it must be heated to high temperatures before it can be molded. The casting temperature is between 1300-1400 °C and the casting shrinkage is 2.0%. The high hardness will make it difficult to polish mechanically. Electrolyte polishing is carried out first and then followed by mechanical polishing so that it does not change the position of the coping. This is related to the better marginal adaptation of Co-Cr coping with a full metal collarless design.[12]

Co-Cr coping material group with full metal collarless design, there is a thin porcelain on the marginal surface, which causes the porcelain to shrink which is not supported by metal during the combustion process, but shrinkage can still be controlled with porcelain application techniques and maximum condensation to minimize the distance. between the porcelain particles and remove a large amount of liquid from the porcelain paste. Reducing the distance between the particles will result in maximum density. Distortion in the thermal cycle of metal porcelain crowns must be taken into account to observe the magnitude of the time and direction of deformation, namely the theory that porcelain combustion shrinkage is a significant causative factor in the distortion process, where distortion has occurred during the initial oxidation process of the alloy. Shrinkage in porcelain can cause metallic contractions that can alter marginal adaptations. By burning at 975˚C the dense mass can reduce shrinkage, so that distortion and cracking can also be prevented through low shrinkage after combustion. [20]

In this modified metal collarless design requires the precision of a technician, where the metal coping is not supported even 1.5 mm shorter than the cervical suffix. The application of a controlled porcelain layer with an expected thickness of 1.5 mm at the cervical end will form a solid mass that can reduce combustion shrinkage, distortion and cracking can also be prevented through low shrinkage after burning so that a smaller marginal gap is obtained. [15]

Table 4 shows the results of the analysis using Independent T-test which states that there is a significant effect on the design of full metal collarless coping with Ni-Cr and Co-Cr coping materials on the marginal adaptation of metal porcelain crowns with p value = 0.029 ($p < 0.05$), where the Co-Cr coping material group with a full metal collarless design showed a smaller marginal gap compared to the Ni-Cr coping material group with a full metal collarless design.

The excess oxide layer on combustion is considered to have an influence on the porcelain metal bond. So that by increasing the combustion temperature to 975˚C the adhesive strength of porcelain metal increases, and the porosity decreases in number and size. This is in accordance with Gupta's 2011 research, namely the size of the pore diameter becomes smaller with increasing the combustion temperature to 975˚C (Gupta, 2011). According to Zhang 2015, stated that as the firing temperature increases, the solubility and dispersion of porcelain and metal will increase. In the porcelain smelting process, the alloy and porcelain elements can dissolve each other, while the atoms diffuse randomly and form an oxide layer as a transition layer. The porcelain components interact with the oxide to form a strong oxide bond between the metal and the porcelain. Porcelain particles will melt and bond with each other when sintering occurs, and the sintered particles will flow and fill the pore space. Metal and porcelain can bond properly with the low fusing porcelain firing temperature so that the porcelain thermal contraction coefficient must match the metal thermal contraction coefficient which affects the marginal adaptation to be good [12.22]

Resistance to change describes the ability of a metal to withstand permanent or gradual changes caused by thermal stress (Anusavice, 2013). At the time of increased combustion there is a coalescence of particles with reduced porosity and increased density, so that shrinkage is reduced, metal contraction is also reduced. At factory standard combustion temperatures, distortion occurs due to the amount of shrinkage that causes the metal to contract. The metal alloy temperature ranges from 1150˚C – 1500˚C, and the low fusing porcelain firing temperature ranges from 850˚C–1100˚C. Melting the metal which is the same as the porcelain firing temperature can cause distortion or melt coping during porcelain firing. The greater the temperature difference between the two materials will further reduce the problems encountered during combustion. The coefficient of thermal expansion of the metal is 13.5-14.5x10-6/°C. Metal and porcelain must have a suitable coefficient of thermal expansion, which is between 0.5-1x10-6/°C, so that the porcelain is subjected to little stress during the cooling process. The metal cover must have an optimal thickness to prevent distortion during the combustion process.[11,12,13,18,21]

Porcelain is a very stiff, hard and brittle material, whose strength is reduced by the presence of surface irregularities or internal voids and is porous. The fine powder form provides a uniform surface compared to the coarse powder form. Combustion at residual pressure can reduce porosity. When porcelain is applied to metal and the two materials are burned together, the porcelain will chemically fuse with the oxides on the metal, forming a strong bond. Porcelain baked at high temperatures can flow and fuse with the oxides on the metal surface. The opaque porcelain must be able to wet the metal surface during combustion to obtain a good chemical bond between the metal-porcelain surface. Porcelain's coefficient of thermal expansion must match that of metal, to improve metal-porcelain bonding.[21]

The porcelain firing process consists of burning opaque, dentin, enamel and glazing. During combustion, the main components of porcelain (Potassium (K), Silicon (Si), Aluminum (Al) interact with oxides to form strong oxide bonds between metal and porcelain. , and the sintered particles will flow, coalesce and fill the pore space. Porcelain particles that are not sintered well, are not able to flow and fill the cavities perfectly will form a large number of pores (Saini et al. 2011). must flow easily over the entire metal surface and adhere to the metal. The ease with which the porcelain flows also affects the area filled in the pores. The high tensile stresses in the porcelain coating can also develop from a mismatch of the coefficient of contraction between the metal and the porcelain. Tensile stresses are transmitted into the restoration by forces occlusal stress will increase the residual thermal tensile stress, thereby affecting marginal adaptation [1 22]

The porosity found in porcelain in the form of small air cavities that are open on the surface will always be encountered. This will allow the entry of bacteria and oral fluids, and as a place for plaque buildup. To avoid this, the surface is glazed to produce a smooth, shiny and waterproof outer layer. The adhesive strength of porcelain metal depends on the good wetting of the porcelain on the metal which shows the chemical compatibility between porcelain and metal. The presence of the oxide adhering to the metal surface moistened by the porcelain provides a favorable transition layer. The atomic diffusion of the metal and porcelain into these oxides is referred to as evidence of chemical bonding. A non-adherent oxide, however, can cause weak boundaries and failure. The presence of surface roughness on the surface of metal oxides can result in mechanical retention at the microscopic level. Porcelain porcelain needs to be minimized in order to obtain the best appearance and optical strength because the pores scatter light, reduce translucency, and can act as initiators of cracks with high stress concentrations, lowering strength in stress and shear. So that the control of porosity will be a fundamental consideration in the design and processing of porcelain. Mechanical vibration is usually used in the first condition to reduce the volume fraction of porosity in the porcelain powder density method, the number and size of the voids depending on the size distribution. The use of carefully controlled vibrations, so that large porosity can be avoided during the combustion process and create a good marginal adaptation.

Conclusion

Co-Cr coping material with modified metal collarless coping design has the best marginal adaptation and is clinically acceptable, so this design can be recommended for clinical application in cases that require maximum esthetics.

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